ROLE OF COLEMAN HATCHERY IN MAINTAINING A KING SALMON RUN

RESEARCH REPORT 47

FISH AND WILDLIFE SERVICE

UNITED STATES DEPARTMENT OF THE INTERIOR

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ROLE OF COLEMAN HATCHERY IN MAINTAINING A KING SALMON RUN

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UNITED STATES
DEPARTMENT OF THE INTERIOR
Fred A. Seaton, *Secretary*
FISH AND WILDLIFE SERVICE

UNITED STATES GOVERNMENT PRINTING OFFICE : 1957

For sale by the Superintendent of Documents, United States Government Printing Office
Washington 25, D. C. - Price 25 cents

ABSTRACT

Coleman Hatchery was built on Battle Creek, a tributary of the Sacramento River in northern California, to compensate for losses of spawning areas of the king salmon (*Oncorhynchus tshawytscha*) that resulted from the construction of Shasta Dam. The river was blocked in 1943, and in 1944 studies were inaugurated at Coleman Hatchery to determine (1) how many of the fish entering the valuable sport and commercial salmon fisheries of California had originally been released from the hatchery, and (2) which was the better practice: to release immature salmon from the hatchery in the spring or to release them in the fall.

Paired groups of immature salmon from the 1944, 1945, 1947, and 1948 broods were marked by amputating fins in certain combinations, and the fish were released in the Sacramento River—one group in the spring and the other in the fall. Fishery workers inspected the landings in the commercial fishery, principally at Pittsburg, Calif., in the years 1947 through 1952, and others examined salmon taken in the sport fishery on the Sacramento River during some of these years. Records also were kept at the Coleman Hatchery on the marked and unmarked king salmon that returned as adults to the hatchery holding areas during the period 1946 to 1952.

The study revealed that king salmon released in the spring from the hatchery were heavier than those released in the fall, but fall-released fish had entered the commercial fishery in greater numbers than had spring-released fish. Most spring-run stock recovered in the spring had been released from the hatchery in the spring, and the greatest proportion of fall-run stock caught in the fall had been released in the fall. Offspring of spring-run salmon tended to return as adults in the spring runs, and offspring of fall-run salmon predominated in the fall runs.

The average annual percentage of king salmon taken in the commercial gill-net fisheries of California from 1944 to 1948 that was attributable to the Coleman Hatchery was conservatively estimated to be 18.91.

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Approved for publication July 31, 1956. Research Report 47.

ROLE OF COLEMAN HATCHERY IN MAINTAINING A KING SALMON RUN

Completion of Shasta Dam and its afterbay, Keswick Dam, early in 1943, blocked the access of migratory fishes to the upstream reaches of the Sacramento River. Consequently, provision had to be made for the important king salmon (*Oncorhynchus tshawytscha*) runs which were now restricted to the downstream areas (Moffett 1949). Coleman Hatchery was built on Battle Creek, a tributary of the Sacramento River, to help perpetuate the displaced king salmon of the upper Sacramento River by supplying additional spawning facilities.

Early in the operation of Coleman Hatchery it became obvious that much had to be learned about the handling of the king salmon if the hatchery was to function properly. To obtain information on the habits and biology of these fish in relation to the hatchery and to the altered river conditions, marking experiments were conducted at the hatchery and in the field. These marking experiments—which were especially designed to determine the value of the hatchery in terms of adult salmon produced, and the best time of the year to release immature salmon from the hatchery—were started at Coleman Hatchery in 1944 with young of the year.

Fish and Wildlife Service personnel who planned and carried out most of the project reported here were Drs. James W. Moffett, Frederic F. Fish, and Oliver B. Cope, with Reed S. Nielson, Daniel W. Slater, John Pelnar, and Leo F. Erkkila. Personnel of the California Department of Fish and Game, Branch of Marine Fisheries, aided in the recovery of marked salmon, and Donald H. Fry, Jr., of that Agency, helped materially by supplying catch data. The U. S. Bureau of Reclamation financed most of the work carried on by the U. S. Fish and Wildlife Service.

SACRAMENTO RIVER KING SALMON

The importance of the Sacramento River system in the production of king salmon must be understood to appreciate fully the problem created by the construction of Shasta Dam and the resulting blocking of the king salmon runs to upstream spawning areas. Fry (1949) has presented an excellent review of the salmon fishery of California.

All of the king salmon caught in the gill-net fishery in California are produced in the Sacramento and San Joaquin river systems, with the Sacramento River segment by far the greater of the two. Dominance of the Sacramento River con-

tribution has been especially marked in recent years when the volume of water discharged from the San Joaquin River has been seriously reduced. Also, the salmon of the San Joaquin River are only lightly exploited by the gill-net fishery because they run mainly during the closed winter period.

With regard to the ocean troll fishery, Hughes [1] reported that tagging experiments show that about 90 percent of the commercial catch off central California south of Point Arena comes from the Sacramento-San Joaquin River system. Of these fish 70 percent are spawned in the upper reaches of the Sacramento and its tributaries. Also, Sacramento River fish make up 28 percent of 254,000 salmon caught off northern California each year.

The contribution of the Sacramento River to the salmon fisheries of the States north of California was revealed in a recent report (Pelgen 1955). Fins were removed from more than 400,000 immature king salmon in the Sacramento River. In the recovery of these marked fish in the ocean commercial fishery, 878 were taken in California waters, while 1,453 were caught in the ocean off Oregon, Washington, and British Columbia.

Thus, the Sacramento River is clearly the chief single source (supplying about 47 percent) of th king salmon taken in the Californi commercial fishery. The annua first wholesale value of the Cali fornia commercial salmon fisher from 1943 to 1952 averaged approxi mately $1,934,500; the Sacrament River portion of this was abou $900,000.

The sport fisheries, ocean trollin and river fishing, account for tre mendous numbers of king salmo originating in the Sacramento Rive and its tributaries. Skinner (1955 estimates that the sport salmo catch in California was 640,00 fish in 1953—430,000 from th ocean and 210,000 from inlan waters. Hughes [1] points out tha about half of the sport salmo catch in the ocean off California i attributable to the Sacrament River. Smith (1950) reports tha in the fall of 1948 approximatel 3,300 king salmon were caught b sportsmen in the Sacramento Rive in the 100 miles below Reddin and that in 1949 approximatel 8,000 king salmon were caught i the same area. Since sport fishe men in other parts of the Sacra mento River system also harveste additional thousands of salmon, th Sacramento River contribute greatly to the inland sport catc of salmon. These facts indicat that the sport fishery for salmo in California approaches, and a times surpasses, the commercia fishery in pounds of salmon landed

[1] Quoted in Outdoor California. *See* Half state's ocean salmon catch produced by Sacramento River. Vol. 15, No. 10, p. 7. October 1954.

COLEMAN HATCHERY

Coleman Hatchery is situated on the north bank of Battle Creek about 6 miles above the junction of that stream with the Sacrament River, in Tehama County, Cali (fig. 1). Following the opening o

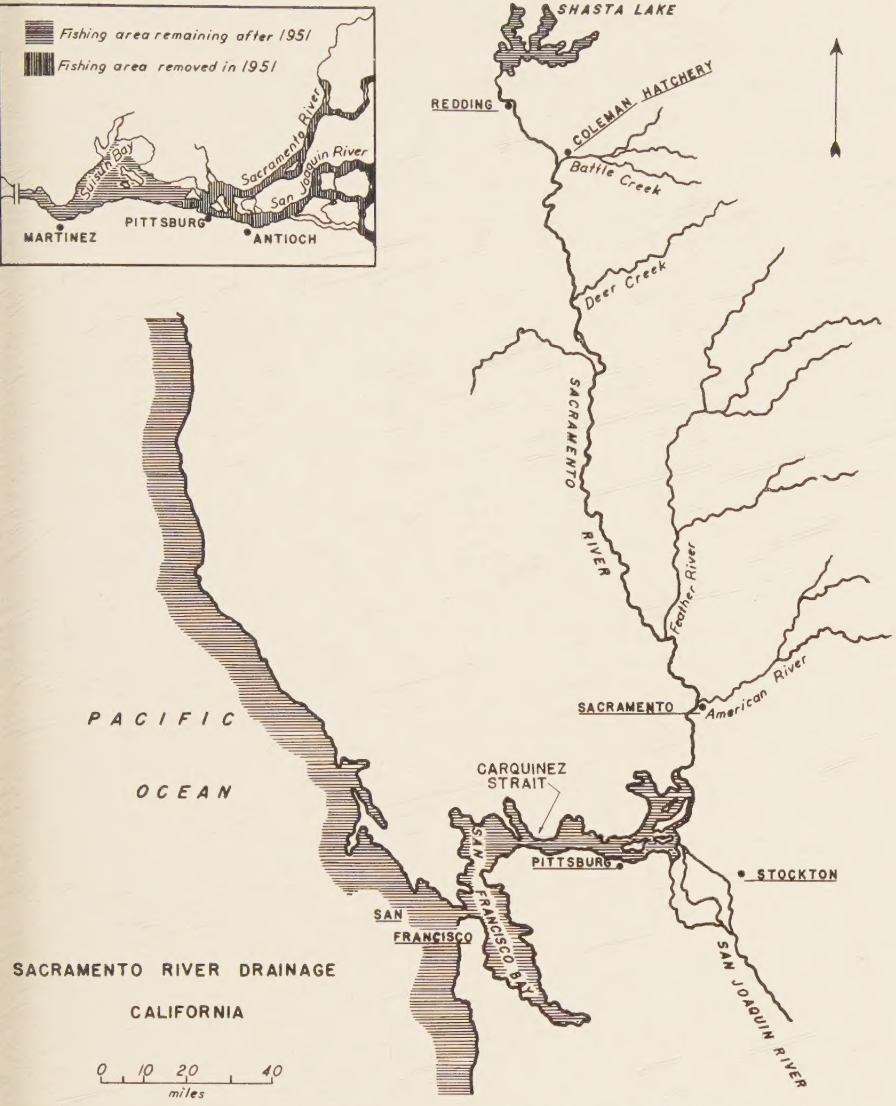

Figure 1.—Sacramento River and tributaries, with important fishery landmarks.

Coleman Hatchery in 1941 and until closure of the old Battle Creek Hatchery after the 1944 season, nearly all of the fish handled at the new hatchery were trapped in the Sacramento River. After the Battle Creek Hatchery was closed Coleman Hatchery also handled salmon trapped in Battle Creek. For a number of years, salmon were trapped in Battle Creek at the historic rack site located about one-half mile below the old hatchery, but now (in 1956) the fish are diverted into holding and spawning ponds at Coleman Hatchery. In their migrations up Battle Creek, spring-run and fall-run salmon, which formerly entered the racked-off area, now enter the holding

ponds at the Coleman Hatchery several miles upstream. Adult fall-run salmon in the Sacramento River are still trapped at Keswick Dam and hauled to the hatchery for spawning.

Facilities at Coleman Hatchery include 288 deep troughs and 28 rectangular concrete ponds, each 130 feet long by 14 feet wide by 4 feet deep. (For further details see Needham, Hanson, and Parker, 1943.) Improvements in the facilities have been made throughout the period of the hatchery's operation. Noteworthy improvements include two large, earthen holding ponds with submerged water intakes for adult salmon. Rearing facilities limit production to a maximum annual output of about 40 million 1½- to 2-inch fingerlings and 2 million 5- to 7-inch fingerlings. The water used in the hatchery is taken from the tailrace of the Coleman power plant of the Pacific Gas and Electric Company and has its origin largely in springs at higher elevations in the Battle Creek drainage.

In the operation of the hatchery, salmon are spawned artificially in the holding areas and the fertilized eggs are taken to the hatchery for incubation and hatching of the eggs and subsequent rearing of the young. Since 1943, from 10 million to more than 40 million fall-run salmon but usually less than 3 million spring-run salmon have been propagated annually at Coleman Hatchery. Fish-planting operations are restricted to the spring and fall seasons to avoid, insofar as possible, the summer loss of fingerlings into the many irrigation canals located downstream along the Sacramen River. The rearing ponds hav direct, screened connections wi Battle Creek so that planting oper tions consist merely in pulling th screens and flashboards at the a propriate time, releasing the fis directly into Battle Creek. On in Battle Creek, the salmon are fr to migrate through the Sacramen River and San Francisco Bay to th Pacific Ocean. At maturity, su viving salmon from these plantin can return to the Battle Creek hol ing ponds where they are trapp and spawned artificially. A co siderable number of salmon spaw naturally in Battle Creek dow stream from the hatchery facilitie and sufficient numbers are permi ted to pass upstream to utilize th limited spawning areas there.

Of much importance in the oper tion of Coleman Hatchery is the r lation between the time of release fingerlings and the time of operati of the irrigation diversions dow stream. Sacramento River has a proximately 300 irrigation dive sions between the mouth of Batt Creek and the city of Sacrament Operation of these pump or gravi diversions ordinarily begins at r duced rates about March 15. Th peak volume of water usually is c verted in July, but even in Apr great amounts of water are remov from the river. Since most irrig tion activity in this area terminat before October 15, the possibili has been considered that the holdi of fingerlings in the hatche through the summer for release the end of the irrigation season ma be more advantageous than the r

ease of them in the spring when irrigation activities are already underway. A third possibility, that of protecting fry and fingerlings by screening, is not yet feasible for the larger diversions on the Sacramento River.

The experiments discussed in this paper concern releases both in the spring and in the fall, so that seasonal comparisons of the numbers of fish which ultimately enter the fishery as adults or return to Coleman Hatchery as adults could be made.

MARKING EXPERIMENTS

The marking experiments were designed to provide two principal categories of information concerning king salmon: (1) The contributions made by Coleman Hatchery to the commercial and sport fisheries, and (2) comparisons between the results of spring and fall releases from the hatchery. The specific questions for which answers were desired were as follows:

1. How many fish produced in the hatchery are caught as adults in the commercial fishery?
2. Do spring-released fish survive in greater or lesser numbers than fall-released fish, measured by returns to the commercial fishery and to Battle Creek?
3. Are fish released in the spring larger or smaller at maturity than those released in the fall?
4. Do spring-released fish or fall-released fish make the greater contribution in total pounds to the commercial fishery?
5. Do the progeny of spring-run and fall-run stocks always return to the river with their ancestral runs regardless of the time of release as fingerlings?

To make the comparisons outlined here, fish were selected at random from both spring-run and fall-run stock and lots of each marked with paired marking combinations (i. e., right ventral-adipose and left ventral-adipose, . . .). Surgical clippers (nail-splitting forceps) of good quality were used to amputate the fins. Marking was completed in late March or early April and the groups of marked fish were inspected carefully for mortality and any signs of fin regeneration (Slater 1949). A group of fish bearing one of a pair of marking combinations was then released in the spring (in March or April) and a group bearing the other of a pair of markings in the fall (October), together with a group of unmarked fish. Thus, a ratio could be established for the number of marked fish released to the total number of fish released from the hatchery (table 1). Data on the adults resulting from these releases were compared following recovery in subsequent years.

Selection of the fin combinations was influenced by several factors. In some instances, it was necessary to use single-fin markings, although not usually desirable, as they were the only type of marking available in certain years. To avoid duplication of marks and the resulting confusion in identifying recoveries, fishery workers on the Pacific coast have adopted a system of allocating marks used in such studies. It was also desirable to select combinations

Table 1.—King salmon marking data, Coleman Hatchery, 1944–49

[RV=right ventral; Ad=adipose; LV=left ventral; D=dorsal; An=anal; LP=left pectoral; RP=right pectora

Year released and stock	Fin mark	Salmon released								
		Number marked	Date	Marked			Unmarked		Ratio marked to total released [1]	Num ber per poun
				Number released in spring	Number held for fall release	Number released in fall	Number released in spring	Number released in fall		
1945:										
Fall-run	RV–Ad	50, 500	4/17/45	49, 911			10, 141, 165		1/204. 185	239
Do	LV–Ad	50, 700	10/16/45		50, 089	42, 181		219, 945	1/6. 214	18.
1946:										
Spring-run	RV–D	51, 251	4/ 8/46	50, 180			720, 536		1/15. 359	250
Do	LV–D	51, 108	10/14/46		50, 278	41, 413		185, 541	1/5. 480	18.
Fall-run	RV–An	51, 906	4/22/46	49, 256			20, 088, 720		1/408. 843	188
Do	LV–An	52, 797	10/14/46		50, 414	41, 918		649, 455	1/16. 493	19.
1948:										
Spring-run	LV	50, 542	3/26/48	50, 394			24, 270		1/1. 482	181
Do	RV	50, 682	10/19/48		50, 508	43, 236		0	1/1. 000	13.
Fall-run	LP	51, 785	4/ 8/48	51, 576			8, 485, 525		1/165. 525	304
Do	RP	51, 226	10/18/48		50, 965	48, 016		1, 499, 480	1/32. 229	17.
Late fall-run	D	53, 548	4/ 8/48	53, 074			0		1/1. 000	785
1949:										
Fall-run	RV–Ad	102, 272	10/15/49		101, 392	95, 900		1, 819, 592	1/19. 974	16
Do	LV–Ad	103, 385	4/ 4/49	102, 513			1, 505, 046		1/15. 682	625
Total		771, 702		406, 904	353, 646	312, 664	40, 965, 262	4, 374, 013		

[1] Ratios based on numbers surviving at time of release.

of fins that would not regenerate easily. For example, ventral-fin marks were preferred to anal-fin marks because the ventral fin regenerates less and is easier to remove in the marking operation.

Sampling of the fishery was accomplished at packing houses in the Pittsburg-Antioch-Martinez area. A fishery worker assigned to a packing house on a particular day examined each salmon for clipped fins as the fisherman turne his catch over to the packe In most years, the A. Paladi plant at Pittsburg was given com plete daily coverage throughou the fishing season, while in othe years a system of random samplin of several packing houses was used Under both systems, sampling wa representative on an areal basi and was adequate from the stand point of the sample size.

CONTRIBUTION OF COLEMAN HATCHERY TO THE GILL-NET FISHERY

Originally it was planned to sample the catches of king salmon taken in the commercial troll fishery along the California coast, in the inland commercial gill-net fishery of the lower Sacramento River and the delta of the Sacramento and San Joaquin Rivers, and in the sport fishery on the Sacramento Rive from the mouth of the river to th city of Redding, to recover th marked fish. Because of the man power shortage and for other rea sons, this plan could not be realized consequently, emphasis was place on the gill-net fishery (table 2

Table 2.—Commercial catches of king salmon in the gill-net fishery, numbers and percentages examined, and average weights, 1946–52

Item	Year						
	1946	1947	1948	1949	1950	1951	1952
Catch:							
Number of pounds	6, 463, 245	3, 380, 484	1, 939, 801	899, 090	1, 211, 513	1, 343, 171	738, 171
Number of fish	[1] 290, 744	149, 315	95, 698	38, 456	[1] 54, 499	[1] 60, 422	[1] 33, 061
Number examined	0	[2] 28, 535	[2] 13, 913	[2] 6, 039	13, 006	10, 796	10, 448
Percentage of total catch examined	0	19. 11	14. 53	15. 70	23. 86	17. 86	31. 60
Average weight (pounds)	[3] 22. 23	22. 64	20. 67	23. 38	[3] 22. 23	[3] 22. 23	[3] 22. 23

[1] Estimated from average weights of samples obtained in 1947, 1948, and 1949.
[2] Estimated from total weight of recovery sample and average weight of 1,127 fish examined in 1947, 1,082 fish in 1948, and 844 fish in 1949.
[3] Combined average weight of samples weighed in 1947, 1948, and 1949.

n which large samples could be readily obtained, and for which accessory data such as weight and time of capture would be available. When marked salmon were recovered from the commercial troll fishery and from the sport fishery, such accessory data were not always available. Identification of ocean recoveries was often impossible because of the multiplicity of marks in the ocean fishery, especially in the early years of this study. Marked fish from Washington and Oregon mingled in the ocean with those marked during this program and made identification difficult.

The present analysis is based mainly on returns from the gill-net fishery, which includes from 10 to 47 percent of the total king salmon landings in California during the years 1946 to 1952. It is assumed (1) that the percentage contribution of Coleman Hatchery is greater to the gill-net fishery than to the ocean troll fishery because the troll catch includes salmon spawned in northern streams (Fry and Hughes, 1951; Neave 1951; Van Hyning 1951); and (2) that the percentage contribution of Coleman Hatchery to the gill-net fishery is less than to the Sacramento River sport fishery because some of the salmon in the gill-net landings originate in the San Joaquin River system.

Sampling in the commercial gill-net fishery resulted in recovery of 197 marked salmon (table 3). No sampling was done in 1946, because the oldest marked fish were then less than 2 years old, and the fall runs of 1947 through 1952 were sampled. The entire landings at Paladini and Sons, Pittsburg, California, were examined in each of these years, as well as frequent samples from various other packing houses in the Pittsburg-Martinez area. Landings at Paladini's are assumed to come from representative fishing areas throughout the delta waters open to fishing. The spring-run catches in the commercial gill-net fishery were sampled at Paladini's in 1949, 1950, and 1951.

Most marked fish came from the fall runs, since the gill-net fishery takes few spring-run fish. This is true partly because the spring run contains less fish than does the fall run, and partly because of the restrictions imposed by the dates open to fishing.

Areas open to the gill-net fishery

Table 3.—Recoveries of marked salmon from the gill-net fishery, by season, fall 1947–52

[S=spring; F=fall; RV=right ventral; Ad=adipose; LV=left ventral; D=dorsal; An=anal; LP=left pectora
RP=right pectoral]

Time of release	Fin mark	Stock	Number of salmon recovered in—												All years	
			1947		1948		1949		1950		1951		1952			
			S	F	S	F	S	F	S	F	S	F	S	F	S	F
1945:																
Spring	RV-Ad	Fall-run		12		12	0	0	0	0	0	0		0		2
Fall	LV-Ad	do		10		20	0	1	0	0	0	0		0		3
1946:																
Spring	RV-D	Spring-run				0	3	0	0	0	0	0		0	3	
Fall	LV-D	do				0	2	0	1	0	0	0		0	3	
Spring	RV-An	Fall-run		0		2	0	1	0	0	0	0		0		
Fall	LV-An	do		0		10	0	2	1	3	0	0		0	1	1
1948:																
Spring	LV	Spring-run					1	1	3	4	2	3		2	6	1
Fall	RV	do					0	1	1	6	2	11		6	3	2
Spring	LP	Fall-run					0	0	0	0	1	4		0	1	
Fall	RP	do					0	0	0	3	0	4		0		
Late fall	D	Late fall-run					0	0	0	0	0	1		0		
1949:																
Spring	LV-Ad	Fall-run							0	3	0	16		14		3
Fall	RV-Ad	do							0	1	1	10		16	1	2
Total				22		44	6	6	6	23	6	49		38	18	17

are shown in the inset in figure 1. Gill netting formerly was permitted from Carquinez Straits through most of Suisun Bay, up the main channel of the Sacramento River to the city of Sacramento, up the San Joaquin River to Stockton, and in many of the larger waterways, such as Steamboat, Sutter, Latham, and Connection Sloughs and Old and Middle Rivers. The California State Legislature closed much of the gill-net fishery by restricting the fishing areas, effective on September 22, 1951. Commercial fishing is now confined to Carquinez Straits and Suisun Bay, and no gill netting for salmon is permitted on the Sacramento or San Joaquin Rivers.

Estimating the contribution

An estimate of the contribution to the gill-net fishery of king salmon produced at Coleman Hatchery is complicated by factors which preclude the use of simple ratio esti mates. Ordinarily, such an esti mate could be developed from data on the total number of salmon in the landings, total number of fish examined, and the total number of marked fish recovered. An analysis of the gill-net fishery, however was complicated by (1) marked fish not being represented in all year classes in the fishery, and by (2) the commercial gear being partially selective.

Marked fish were released from Coleman Hatchery in 1945, 1946 1948, and 1949 (table 1). The commercial landings in the year immediately following the first re leases, therefore, contained no fish of the older year classes, and of course, no fish from a 1947 releas appeared in any year's landings In the 1951 and 1952 samplings o the commercial catch, no fish of th 1944 and 1945 year classes wer taken. Thus, marked salmon wer

issing from some year classes in
ie fishery in every year of collec-
on. This situation made it im-
ossible to use marked-fish-released
total-fish-released ratios for the
arked-fish-recovery sample as a
hole, and necessitated consider-
ion of each year class in each year
collection. To determine the
ear-class distribution of each year's
ndings, the fish were aged by
ading their scales. In the follow-
g discussion we will apply the
ppropriate ratio between each lot
marked fish to the numbers of
sh bearing that mark recovered
each year's marked-fish-recovery
mple as the first step in estimat-
g the contribution to the gill-net
shery of king salmon produced at
oleman Hatchery.

The other complicating factor,
lectivity of gear, was introduced
y the commercial gear, sometimes
lowing small salmon, mainly 2-
ear-olds, to escape. Escapement
this year class, however, was not
mplete, and some marked fish
ere taken in the fishery, but relia-
bility of the estimate for this year class in the commercial fishery is questionable.

To compute the contribution of king salmon to the commercial gill-net fishery by the Coleman Hatchery, it was necessary to know for each year the fishery was sampled not only the ratio of the number of marked fish released to the total number of fish released from the hatchery, the numbers of each mark recovered, and the total number of fish in the mark-recovery sample, but also the numbers of fish taken by the gill-net fishery and the year-class composition both of the recovery sample and of the gill-net catch. Table 4 summarizes the releases from Coleman Hatchery during the period of these marking experiments. Total releases are shown, and the numbers of marked fish are indicated; spring-run, fall-run, and late fall-run stocks are listed separately. From these data were derived the marked-to-total ratios, as shown in table 1. The numbers of fish of each mark recovered from

Table 4.—King salmon released at Coleman Hatchery, by years, 1945–49

[arkings in parentheses; RV=right ventral; Ad=adipose; LV=left ventral; D=dorsal; An=anal; LP=left pectoral; RP=right pectoral]

Year leased	Spring-run stock				Fall-run stock				Late fall-run stock	
	Spring-released		Fall-released		Spring-released		Fall-released		Spring-released	
	Total number released	Number marked and released	Total number released	Number marked and released	Total number released	Number marked and released	Total number released	Number marked and released	Total number released	Number marked and released
5	3, 184, 067	0	170, 011	0	10, 191, 076	49, 911 (RV–Ad)	262, 126	42, 181 (LV–Ad)	0	0
6	770, 716	50, 180 (RV–D)	226, 954	41, 413 (LV–D)	20, 137, 976	49, 256 (RV–An)	691, 373	41, 918 (LV–An)	0	0
7	1, 809, 119	0	574, 543	0	22, 810, 588	0	590, 991	0	0	0
8	74, 664	50, 394 (LV)	43, 236	43, 236 (RV)	8, 537, 101	51, 576 (LP)	1, 547, 496	48, 016 (RP)	53, 074	53. 074 (D)
9	0	0	0	0	1, 607, 559	102, 513 (LV–Ad)	1, 915, 492	95, 900 (RV–Ad)	0	0

the gill-net fishery are shown in table 3.

The total numbers of fish in the catch samples scrutinized for marked fish usually were determined by actual count, but in 1947 and 1949 estimates of these numbers were made by dividing the total weight of the landings sampled by the average weight of a representative group of the fish. The average weight was determined by weighing from 800 to 1,200 fish from a landing (table 2). The weight and estimated number of fish in each year's landings of the commercial gill-net fishery are also given in table 2. The year-class composition of the gill-net catches was determined from samples by scale analysis, and from the indicated compositions (table 5), the numbers of fish of each year class were calculated both for the mark-recovery sample and the gill-net catch for each year of the study.

The number of salmon from Coleman Hatchery in the mark-recovery sample was computed from marked-to-total ratios by means of the simple relation

$$AB=C$$

where

A=the factor for projecting total release from number of marked fish released from Coleman Hatchery (from marked-to-total ratio),

B=the number of fish with the respective fin mark recovered in the fishery, and

C=the number of Coleman Hatchery fish calculated to be present in the sample from the fishery.

Table 5.—Year-class composition of fa run king salmon taken in the gill-net fishe

Year class [1]	Percentage composition of fish land in—					
	1947	1948	1949	1950 [2]	1951	19
II	6.80	5.21	0.46	3.80	2.73	3
III	37.80	30.55	45.00	35.45	28.47	35
IV	47.90	44.80	48.50	50.42	60.45	50
V	7.50	17.01	6.00	9.72	8.98	9
VI	0.00	2.43	0.00	0.61	0.00	0
Total fish sampled	450	260	211	------	260	

[1] These ages are actually 1 to 3 months less th indicated, judging from the time of hatching.
[2] Averages of values for 1947, 1948, 1949, and 1951.

Each mark (left ventral–adipos right pectoral; . . .) was treat separately in each year of recover

These calculated contributio were then summed by year class for each year of recovery, and fro these totals the percentage co tribution of Coleman Hatchery the mark-recovery sample and the gill-net fishery was determin through knowledge of the yea class composition of the samp and of the fishery.

Summaries of the estimates Coleman Hatchery's contributio to the gill-net fishery are shown table 6. Here, each brood fro that of 1944 to that of 1948 treated separately as it enter the fishery of each recovery yea from 1947 to 1952.

To illustrate, the commerci gill-net catch of king salmon in 19 can be used as an example of t method. In the sampling of ma returns, 10,796 salmon were exa ined (table 2), and 55 marked fi were found. These 55 fish we from seven groups of markin and two year classes, and each the seven markings had differe marked-fish-released to total-fis

Table 6.—Marked king salmon from Coleman Hatchery recovered in the gill-net fishery, by year-class, brood-year, and year recovered

Year class	1944 brood	1945 brood	1947 brood	1948 brood	Mean percent
Year-class II:					
Year recovered		1947	1949	1950	
Number in sample		0	4	67	
Percent in sample		0.00	14.29	13.99	
Percent in gill-net fishery		0.00	0.07	0.53	0.13
Year-class III:					
Year recovered	1947	1948	1950	1951	
Number in sample	2,512	983	114	467	
Percent in sample	23.29	23.12	2.61	15.20	
Percent in gill-net fishery	8.80	7.06	0.93	4.33	6.33
Year-class IV:					
Year recovered	1948	1949	1951	1952	
Number in sample	2,574	499	978	540	
Percent in sample	40.98	17.04	14.99	10.21	
Percent in gill-net fishery	18.36	8.26	9.06	5.15	12.15
Year-class V:					
Year recovered	1949	1950	1952		
Number in sample	6	71	9		
Percent in sample	1.65	5.87	0.88		
Percent in gill-net fishery	0.10	0.57	0.09		0.30
Percent recovered, 1947–52					18.91

released ratios. The data for each mark were treated separately by means of the formula $AB=C$ as follows:

Brood, year class, and fin mark	Number of fish recovered	Estimated number of hatchery fish in sample
1947 brood:		
Year-class IV:		
Left ventral	5	$\frac{1.482}{1}\times 5 = 7$ fish
Right ventral	13	$\frac{1.000}{1}\times 13 = 13$ fish
Left pectoral	5	$\frac{165.525}{1}\times 5 = 828$ fish
Right pectoral	4	$\frac{32.229}{1}\times 4 = 129$ fish
Dorsal	1	$\frac{1.000}{1}\times 1 = 1$ fish
Total	28	978 fish
1948 brood:		
Year-class III:		
Right ventral-adipose	10	$\frac{19.974}{1}\times 10 = 200$ fish
Left ventral	17	$\frac{15.682}{1}\times 17 = 267$ fish
Total	27	467 fish
Grand total	55	1,445 fish

Thus, we calculated that 1,445 of the 10,796 fish in the 1951 mark-recovery sample came from Coleman Hatchery. Since no 2-year-old or 5-year-old fish (and probably no 6-year-old fish) from the Coleman Hatchery marking experiments could be present (no fish were marked in 1947 or 1950), only year-classes III and IV could have contributed to the fishery. To determine how many of the 10,796 fish belong to the 3-year-old and 4-year-old groups, we refer to the age composition of a sample of fish collected in 1951 (table 5). Scale studies indicated that the 3-year-olds comprised 28.47 percent of the fish taken in the gill-net fishery, and the 4-year-olds 60.45 percent. Applying these data to the mark-recovery sample, we find that 28.47 percent of the 10,796 fish equals 3,073 fish, and that 60.45 percent equals 6,526 fish. Of the calculated 3,073 3-year-olds in the mark-recovery sample, 467, or 15.20 percent, are assignable to Coleman Hatchery, so that 4.33 percent (28.47×0.1520) of the entire number of fish taken by the gill-net fishery in 1951 is

assignable to the hatchery as its contribution of 3-year-old fish. Similarly, 978, or 14.99 percent, of the calculated 6,526 4-year-olds in the mark-recovery sample are assignable to Coleman, and thus 9.06 percent (60.45×0.1499) of the 1951 catch is assignable to Coleman as the hatchery's contribution of 4-year-olds to the commercial gill-net fishery. As shown in table 6, similar calculations have been made for the mark-recovery samples for each year that the fishery was sampled.

Determination of the average contribution of Coleman Hatchery to the gill-net fishery can be made when the mark-recovery samples have been calculated for each year. The averages of the percentage contributions to the gill-net fishery of all samples for all year classes (3 samples each for year-classes II and V and 4 samples each for year-classes III and IV) are combined to give the estimate of the average contribution from Coleman Hatchery. The estimate as calculated from the present data is 18.91 percent (table 6).

It should be emphasized that this calculated average contribution of Coleman Hatchery relates only to the gill-net fishery. The hatchery's contribution of king salmon to the ocean troll fishery (sport and commercial) and to the inland sport fishery may be of comparable magnitude, but data are incomplete or lacking for these fisheries, as previously indicated.

Further, it is likely that our estimate of the contribution of Coleman Hatchery to the gill-net fishery is low as a result of (1) the poorer survival of marked fish than of unmarked fish, and (2) regeneration of poorly clipped fins, which makes the marks unrecognizable. Evidence of the operation of the first factor on sockeye salmon has been presented by Foerster (1936) and on spiny-rayed fish by Ricker (1949). The conclusions of these investigators were that survival of marked fish may be only 40 to 50 percent that of unmarked fish. Evidence obtained in the present study indicates poor survival of fish marked by removal of anal and pectoral fins, as discussed later.

Concerning the second factor, regeneration of clipped fins, much evidence exists regarding the possible introduction of error because of this factor (Rich and Holmes, 1929; Shetter 1951; and others). Slater (1949) has analyzed the extent of operation of this factor in relation to the markings used in this study. The effect of both regeneration of clipped fins and poorer survival of marked fish is to reduce the apparent contribution of Coleman Hatchery to the commercial gill-net fishery, but evidence is insufficient to permit a correction of the estimated contribution.

The frequency of occurrence of fish naturally lacking fins by reason of heredity or accident is inconsequential when paired-fin marks are used, but it is of demonstrated importance when single-fin marks are employed (Rich and Holmes, 1929). The effect of this factor has been to increase the apparent contribution of Coleman Hatchery to the gill-net fishery in the four instances where single-fin marks were used. Corrections were not attempted in

hese cases because we lack evi-ence of the extent of occurrence of fish with missing fins in the California salmon populations.

COMPARISON OF RETURNS FROM SPRING AND FALL RELEASES

The second phase of our study of he role of Coleman Hatchery in aintaining the king salmon runs the Sacramento River dealt with comparison of the results of re-asing the salmon from the hatch-y ponds in the spring and in the ll. Since information was desired s to the relative survival of fish eleased in the two seasons and lso as to the size each group of sh attained, marked salmon re-overed from all sources, the gill-et fishery, ocean trolling, and ocean ort fishing, were compared with espect to both total numbers and eight of the fish taken. A com-arison was also made of the num-ers of marked fish from the spring nd fall releases that returned to he hatchery ponds (table 7). Since able 7 lists recoveries of marked sh from all reliable sources, its ata differ from those of table 3 hich include only returns from the ample used to calculate Coleman latchery's contribution to the gill-et fishery.

Proportion of spring and fall releases

Comparisons between returns om spring and fall releases show at fish released in the fall return s adults in greater numbers than o spring-released fish. The super-ority in fall returns was greater for ose fish returning to the hatchery an for those taken in the fishery.

Among those fish entering the fishery, 23 comparisons could be made between spring-released and fall-released fish (table 7). Fish released in the spring returned in greater numbers in 9 instances, the fall-released fish were more numerous in 11, and the returns were equal in number for the two groups in 3. If the total of all returns to the gill-net fishery from spring releases is compared with that from fall releases for the entire 6 years, it is seen that there were 166 returns from the spring releases as against 186 from the fall.

Marked salmon from the two groups of releases exhibited a greater difference in number of returns to Coleman Hatchery than to the gill-net fishery. Of 19 comparisons that could be made for marked fish recovered in the fishery, spring-released returns were greater in 4 and fall-released returns in 14, and in 1 comparison the groups were equal in number. Total returns to Coleman Hatchery were 118 spring releases, and 253 fall releases. When returns to the fishery are combined with returns to Coleman Hatchery, it is seen that spring-released returns numbered 284, while fall-released fish numbered 439.

These results, when weighted as explained on page 19, suggest that salmon released from the hatchery in fall months have a somewhat higher survival rate than those re-

Table 7.—Recoveries of marked salmon from all sources, by season, 1946–52

[S=spring; F=fall; RV=right ventral; Ad=adipose; LV=left ventral; An=anal; D=dorsal; LP=left pectora RP=right pectoral]

A. IN THE FISHERIES

Time of release	Fin mark	Stock	Number of salmon recovered in—														All years	
			1946		1947		1948		1949		1950		1951		1952			
			S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	
1945:																		
Spring	RV Ad	Fall-run				26		24										
Fall	LV-Ad	do				21		33		1								
1946:																		
Spring	RV-An	Fall-run						7		2								
Fall	LV-An	do						12		7		3						
Spring	RV-D	Spring-run						1	3		1						4	
Fall	LV-D	do							2		2						4	
1948:																		
Spring	LV	Spring-run							1	1	14	4	2	6		7	17	
Fall	RV	do								2	2	7	2	13		7	4	
Spring	LP	Fall-run									1	1	1	5			2	
Fall	RP	do										4		7				
1949:																		
Spring	LV Ad	Fall-run										3		31		25		
Fall	RV-Ad	do										1		24		36		
Total																	31	3

B. AT COLEMAN HATCHERY

Time of release	Fin mark	Stock	Number of salmon recovered [1] in—							All yea
			1946	1947	1948	1949	1950	1951	1952	
1945:										
Spring	RV-Ad	Fall-run	14	7	2					
Fall	LV-Ad	do	15	14	5	1				
1946:										
Spring	RV-An	Fall-run		12		1				
Fall	LV-An	do		14	3	5				
Spring	RV-D	Spring-run								
Fall	LV-D	do		1		2				
1948:										
Spring	LV	Spring-run					6	5	12	
Fall	RV	do					3	4	14	
Spring	LP	Fall-run				2	3		2	
Fall	RP	do				2	10	19		
1949:										
Spring	LV-Ad	Fall-run					16	14	22	
Fall	RV-Ad	do					15	58	68	
Total										3
Grand total										7

[1] Recoveries at Coleman Hatchery are listed according to year only, since a mixing of spring and fall ru occurred in the holding ponds.

leased in the spring (fig. 2). The higher survival rates of fish planted in the fall is to be expected because the fish are larger when released than are fish released in the spring. Actually, a more decided difference in survival rate might be anticipated in view of the difference in size at time of release. Table 1 data show that the spring-release salmon numbered from 181 to 30 per pound (excluding the releas from late-fall stock, which are n considered here in the paired e periments), whereas the fish r leased in the fall ranged from 13 to 19.1 per pound. In other word the largest spring releases averag

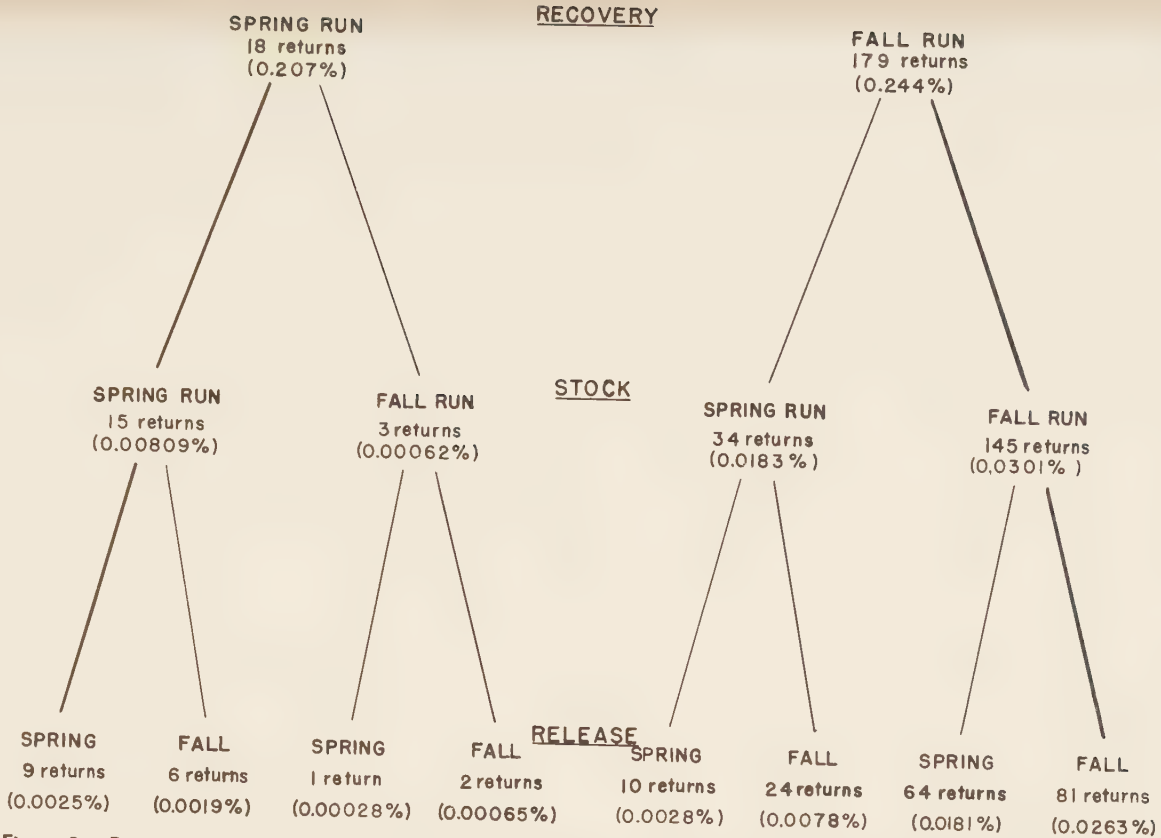

Figure 2.—Returns of marked fish according to time of release, identity of stock, and time of recovery. Numbers refer to fish recovered, and percentages refer to weighted values.

0.09 ounce, while the smallest fall releases had an average weight of a little more than 0.80 ounce; thus, the salmon released in the fall were at least 9 times as heavy as those released in the spring.

Comparison of weights

Comparisons between weights of fall-run, spring-released and fall-released salmon that were taken as 3- and 4-year-olds in the gill-net fishery or recovered at Coleman Hatchery are shown in table 8. Among the 3-year-old marked fish, spring-released males averaged 5.20 pounds heavier than fall-released males and spring-released females averaged 3.62 pounds heavier than fall-released females. Among the 4-year-old returns, spring-released males averaged 9.79 pounds heavier than fall-released males and spring-released females were 2.09 pounds heavier than fall-released females.

The difference in growth rate between salmon released in the spring and those released in the fall, as manifested by weights of returning adults, is believed to originate in differences in food supply during the first year. Spring-released salmon, inhabiting the rich waters of lower Sacramento River, San Francisco Bay, and the Pacific Ocean, evidently have a feeding advantage over hatchery-held salmon released in October.

In the preceding discussion it has been shown that a larger proportion of fall-released salmon than of spring-released salmon returned as adults, especially to Coleman Hatchery. It has been shown further that fish released in the spring

Table 8.—Weights of marked fall-run fish returned to the gill-net fishery and to Coleman Hatchery

Group	Number of fish	Total weight (pounds)	Average weight (pounds)
Year-class III:			
Fall-released males	20	286.1	14.3
Spring-released males	27	526.7	19.5
Difference			5.2
Fall-released females	16	230.7	14.4
Spring-released females	20	360.7	18.0
Difference			3.6
Year-class IV:			
Fall-released males	20	420.2	21.0
Spring-released males	18	554.4	30.8
Difference			9.7
Fall-released females	35	687.4	19.6
Spring-released females	21	456.3	21.7
Difference			2.0

returned to the fishery and to the hatchery as heavier adults than those released in the fall. The question naturally arises as to which group actually contributes the greater weight of flesh to the fishery.

The actual weights of all salmon returned to the gill-net fishery and to Coleman Hatchery have been tabulated according to ages at recovery for each pair of recovery groups (table 9). Returns to the fishery were greater in total weight for fish released in the spring than for fish released in the fall. The chi-square value for the test of significance of the difference between total weights of spring-released and fall-released salmon is 3.70, which is significant at the 0.058 level.

In returns to Coleman Hatchery fish released in the fall returned much greater weight than did fish released in the spring. The chi-square value obtained from a test of the significance of the difference in total weights of the two groups is 109, which is highly significant. The greater total weight of fall

Table 9.—Marked salmon returned to the gill-net fishery and to Coleman Hatchery, by season of release from the hatchery

RV=right ventral; Ad=adipose; D=dorsal; An=anal; LV=left ventral; LP=left pectoral; RP=right pectoral

Time of release and age at recovery	To gill-net fishery		To Coleman Hatchery	
	Number of fish	Total weight (pounds)	Number of fish	Total weight (pounds)
SPRING RELEASES:				
Year-class II:				
RV–Ad	0	0	14	86.65
RV–D	0	0	0	0
RV–An	0	0	12	47.30
LV	2	25.00	0	0
LP	0	0	2	(1)
LV–Ad	3	21.00	16	78.75
Subtotal	5	46.00	44	212.70
Year-class III:				
RV–Ad	26	492.40	7	104.75
RV–D	1	18.00	0	0
RV–An	7	99.30	0	0
LV	18	222.00	6	68.00
LP	2	22.00	3	47.00
LV–Ad	19	379.00	14	163.00
Subtotal	73	1,232.70	30	382.75
Year-class IV:				
RV–Ad	25	628.05	2	40.00
RV–D	3	64.00	0	0
RV–An	2	47.00	1	(1)
LV	7	174.50	5	60.00
LP	6	123.75	0	0
LV–Ad	14	374.20	22	430.75
Subtotal	57	1,411.50	30	530.75
Year-class V:				
RV–Ad	0	0	0	0
RV–D	1	25.00	0	0
RV–An	0	0	0	0
LV	7	114.85	10	165.50
LP	0	0	2	(1)
LV–Ad	0	0	0	0
Subtotal	8	139.85	12	165.50
Total, spring releases	143	2,830.05	116	1,291.70
Average weight		19.79		11.64
ALL RELEASES:				
Year-class II:				
LV–Ad	0	0	15	56.10
LV–D	0	0	1	2.80
LV–An	0	0	13	30.35
RV	1	15.00	0	0
RP	0	0	2	(1)
RV–Ad	1	6.00	15	47.50
Subtotal	2	21.00	46	136.75
Year-class III:				
LV–Ad	21	350.30	14	100.40
LV–D	0	0	0	0
LV–An	12	148.90	3	15.50
RV	9	157.25	2	7.00
RP	4	63.00	10	71.75
RV–Ad	12	161.00	57	381.00
Subtotal	58	880.45	86	575.65
Year-class IV:				
LV–Ad	34	709.30	5	55.50
LV–D	1	18.00	2	(1)
LV–An	7	128.00	5	(1)
RV	14	278.75	3	43.50
RP	4	77.00	16	202.00
RV–Ad	16	295.00	64	981.00
Subtotal	76	1,506.05	95	1,282.00
Year-class V:				
LV–Ad	1	35.00	1	(1)
LV–D	2	39.50	0	0
LV–An	3	45.00	0	0
RV	7	101.50	11	159.50
RP	0	0	0	0
RV–Ad	0	0	0	0
Subtotal	13	221.00	12	159.50
Total, fall releases	149	2,628.50	239	2,153.90
Average weight		17.64		9.41

[1] Data not available.

released fish from Coleman Hatchery like that of the greater numbers returned, appears to result from selective escapement from the gill-net fishery due to the smaller size of fall-released fish at maturity. The differences in average weights of fish taken in the gill-net fishery and those returning to Coleman reflect not only this selection by the fishery, but also the loss in weigh which accompanies the upstream migration of the salmon and ripening of the sex products.

DO SPRING-RUN AND FALL-RUN STOCKS RETAIN IDENTITIES?

It was hoped that these marking experiments would reveal whether offspring of spring-run fish return to spawn in the spring and those of fall-run stock in the fall. Although evidence is not complete, some general assumptions relating to this question are possible from the results, and some considerations are thought to be significant in interpreting these results. The considerations concern the mixing of stocks which has occurred to some extent in the hatchery operations on Battle Creek and naturally in the Sacramento River downstream from Shasta Dam.

In 1945, when operation of Shasta Dam first appreciably influenced ecological conditions in the Sacramento River, it was observed that few spring-run salmon ascended the river past Balls Ferry fish rack and counting structure (Moffett 1949). The fish apparently were retarded in their movement up the river by cold water in the downstream reaches, and it has been assumed that they moved upstream just ahead of the fall-run salmon. This behavior, together with the fact that the two runs were forced to spawn on the same riffles, with the blocking of the river at Keswick Dam, is presumed to have brough about some mixing of the two stock during the period when their spawn ing periods overlap in September The only practical distinction be tween the runs has been thei seasons of spawning. At the hatch ery, beginning with the third seaso of operation, in 1945, the dividin point between the spawning season of the two runs has been more o less arbitrarily set at September 2

A definitive distinction betwee stocks, based on time of migratio has been impossible at Colema Hatchery. A true spring run ha not been observed in any numbe either in Battle Creek or belo Keswick Dam since the season 1945. It is probable that spring run fish have continued to remai over summer in the cool waters large pools in the Sacramento Riv between the city of Red Bluff an the mouth of Battle Creek, ascen ing the river and Battle Creek ju ahead of the fall run. Catches spring-run salmon through the sun mer by the sport fishery in the middle reaches support this beli

Because the commercial gill-n fishery takes few spring-run salmo the marked-fish recoveries from t spring run were too small f

tatistical comparison. Eighteen arked salmon were recovered dur- g the spring run from the gill-net shery, 3 from fall-run stocks (table) and 15 from spring-run stocks. f the 15 fish of spring-run origin, were released from Coleman atchery in the spring, and 6 in ie fall.

Of the 179 fall-run recoveries om the gill-net fishery listed in able 3, 34 were from spring-run ock, and 145 from fall-run stock. f the 145 salmon, 64 were released om Coleman Hatchery in the ring, and 81 were released in the ll (fig. 2).

To the extent that reliance can e placed on these data, it is ncluded that salmon of spring-run ock tend to return in the spring n and that salmon of fall-run ock tend to return in the fall run. lost spring-run-stock recoveries in ie spring were released in the ring, while most fall-run-stock coveries in the fall were released the fall.

The recoveries of marked fish are expressed in both weighted and unweighted values in figure 2. Weighting compensates for inequalities between spring and fall data with respect to numbers of each group released, numbers of each stock marked (table 1), and numbers of recovered fish examined (table 2). Weighting was accomplished by expressing numbers of recoveries as percentages of total numbers of fish landed. Reference to table 1 shows that 406,904 fish marked were released in the spring, and 312,664 were released in the fall. A total of 185,223 marked fish of spring-run stock was released, while 481,271 of fall-run stock were released. In the recovery program, 8,656 spring-run fish and 73,337 fall-run fish were examined. Recovery numbers are given as percentages (in parentheses) of these totals in figure 2, and represent weighted values. The weighted values suggest the same dominant relationships indicated by the unweighted values (actual recovery numbers).

EFFICIENCY OF FIN MARKS

A study such as the present one ust always consider the efficacy the marking method when results e evaluated. Clipped fins are metimes subject to regeneration d may be difficult to recognize in ie recovery program. Thus, some easure of the effectiveness of the arking method is desirable for nsideration in the analysis.

Some evidence of the efficiency of ie marks produced by removal of fferent combinations of fins is tained by summarizing certain data that were presented in table 7. Comparison of these data (table 10) suggests pronounced differences in the efficiency of the different fin combinations in determining the percentage of the returns, e. g., 1945 releases as compared with 1946 releases. These differences are in line with observations on the fingerlings with respect to differences in the recognition value of the marks used on these particular releases, but they further suggest that survival of the marked salmon may be

Table 10.—Comparison of returns, by fin combinations

[LV=left ventral; Ad=adipose; RV=right ventral; An=anal; LP=left pectoral; RP=right pectoral]

Fin-mark combination	Year released	Stock	Total number released	Total number returned [1]	Total returns per 1,000
LV–Ad and RV–Ad	1945	Fall	92,092	163	
LV–Ad and RV–Ad	1949	Fall	198,413	313	
LV and RV	1948	Spring	93,630	112	
LV–An and RV–An	1946	Fall	91,174	66	
LP and RP	1948	Fall	99,592	57	

[1] These returns are based on incomplete coverage of the commercial and sport fisheries and complete coverage Coleman Hatchery: they should not be considered to be total contribution to catch and escapement since th have not been weighted.

more greatly influenced by removal of pectoral and anal fins than of ventral fins.

The apparent differences in the efficiency of the various fin combinations appear to be greater than could be expected solely on the basis of differences in regeneration of fins or in recognition values. Evidence as to differential survival between ventral-fin-clipped trout and pectoral-fin-clipped trout has been presented by Wales (1947). He o served trout for 1 year following f removal and concluded that "The does seem to be a considerably be ter survival among those marke by removal of a ventral fin th among those marked by removal a pectoral." Ricker (1949) h presented an interesting discussi of such differential mortality rat among spiny-rayed fish followi removal of fins.

SUMMARY

Coleman Hatchery was constructed on Battle Creek, a tributary of the Sacramento River in California, to accommodate the adult king salmon (*Oncorhynchus tshawytscha*) expected to collect below Shasta Dam when that structure blocked the Sacramento River in 1943.

Salmon marking experiments were undertaken early at Coleman Hatchery for the two-fold purpose (1) of determining the hatchery's contribution to the fishery and to the maintenance of its own Battle Creek run, and (2) of learning how spring-released fingerlings compare with fall-released salmon with respect to survival and weight at maturity. Immature salmon, marked by clipping different combinations of fins, were released in paired group One group of each pair of markin was released from Coleman Hatc ery in the spring, and the oth group was held at the hatchery ov the summer and released in the fa Recoveries of marked fish we made in the gill-net fishery, in t river sport fishery, in the ocean tr fishery, and during the migration salmon into Battle Creek, whe Coleman Hatchery is located.

In calculating Coleman Hatc ery's contribution to the fisher only the gill-net fishery was consi ered because of the paucity of da from the other commercial fisheri and the sport fishery. Since t catch consisted of fish from seve year classes, and since marked fi

ould not have been present among ll year classes in each year of re-overy, it was necessary to analyze ach year class separately in deter-ining the hatchery's contribution o the gill-net fishery. The present nalysis indicates that in the years 947 through 1952 Coleman Hatch-ry's minimum average contribu-on to the catch of the gill-net shery was 18.91 percent.

Comparisons of returns to the ill-net fishery and to Coleman latchery of adult marked salmon rom both spring and fall releases ndicated that fish from spring re-ases averaged larger than those rom fall releases, but that some-hat more fish were recovered from ll releases than from spring. The reater return of fall-released fish was more marked at Coleman Hatchery than in the commercial fishery. Thus, spring-released fish contributed the greater weight to the gill-net fishery, while fall-released fish contributed the greater weight to Coleman Hatchery returns.

With regard to retention of identity of spring-run and fall-run stock, the data indicate that progeny of spring-run salmon tend to return as adults in the spring run, and that progeny of fall-run salmon tend to return in the fall run. Most spring-run-stock recoveries taken in the spring had been released from the hatchery in the spring, while most fall-run-stock recoveries taken in the fall had been released from the hatchery in the fall.

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U. S. GOVERNMENT PRINTING OFFICE: 1957 O -419546